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A review of the genus *Bulbothrix* Hale: the species with medullary salazinic acid lacking vegetative propagules

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Abstract

Descriptions are presented for the seven known *Bulbothrix* (Parmeliaceae, Lichenized Fungi) species with salazinic acid in the medulla and without vegetative propagules. *Bulbothrix continua*, previously considered as a synonym of *B. hypocraea*, is recognized as independent species. The current delimitations are confirmed for *B. enormis*, *B. hypocraea*, *B. meizospora*, *B. linteolocarpa*, *B. sensibilis*, and *B. setschwanensis*. New characteriscs and range extensions are provided.

Key words

Parmeliaceae, *Parmelinella*, norstictic acid, bulbate cilia

Introduction

The genus *Bulbothrix* Hale was proposed for the group of species called *Parmelia* Series *Bicornutae* (Lynge) Hale & Kurokawa (Hale 1974). This group is characterized by small, laciniate and usually adnate thalli, bulbate marginal cilia, an upper cortex containing atranorin, with pored epicortex, without pseudocyphellae, with isolichenan in the cell walls, simple to branched cilia and rhizinae, smooth to coronate apothecia, hyaline unicellular ellipsoid to bicornute ascospores 5.0–21.0 × 4.0–12.0 µm, and bacilliform to bifusiform conidia 5.0–10.0× 0.5– 1.0 µm (Hale 1976a, Elix 1993, Elix 1994).

Crespo et al. (2010) present a revised generic concept of Parmelioid lichens based on molecular, morphological and chemical evidences. They show that *Bulbothrix* is nested in the *Parmelina* clade and some species are grouped with *Parmelinella*, making

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the genus paraphyletic. The *Bulbothrix* species with salazinic acid, the subject of this study, may actually belong to the genus *Parmelinella*, or even be another small genus closely related to it (Divakar et al. 2006, Crespo et al. 2010). A new generic arrangement of *Bulbothrix* species is not be subject of the present study, however. The type species of *Bulbothrix* is *B. semilunata* (Lynge) Hale, characterized by narrow sublinear laciniae, apically branched cilia and rhizines, coronate apothecia, and bicornute ascospores. This species also lacks medullary substances.

During an unpublished revision of the genus *Bulbothrix* (Benatti 2010) the type specimens and additional material of all *Bulbothrix* species were studied. They appeared to have cilia with hollow basal bulbs, which contain differentiated cells and a characteristic oily substance (Hale 1975, Feuerer and Marth 1997, Benatti 2011). The first published part of Benatti's (2010) thesis concerns new combinations of four species, *Hypotrachyna tuskiformis* (Elix) Benatti & Marcelli, *Parmelinopsis pinguiacida* (Louwhoff & Elix) Marcelli & Benatti, *P. subinflata* (Hale) Benatti & Marcelli and *Parmotrema yunnanum* (Sheng L. Wang, J.B. Chen & Elix) Marcelli & Benatti, previously placed in *Bulbothrix* (Benatti and Marcelli 2010) and excluded due to the lack of true bulbate cilia. The second part treats the species containg medullary norstictic and protocetraric acids (Benatti 2012). This paper is the next in the series and presents the results for the seven species with medullary salazinic acid [*Bulbothrix continua* (Lynge) Hale, *B. enormis* (Hale) Krog, *B. hypocraea* (Vainio) Hale, *B. linteolocarpa* Marcelli, *B. meizospora* (Nylander) Hale, *B. sensibilis* (Steiner & Zahlbruckner) Hale and *B. setschwanensis* (Zahlbruckner) Hale], that do not form isidia, soredia, lacinulae or pustules.

For a comprehensive understanding and easy assessment of all the data on the review of this genus comprising ca. 60 species gathered in an unpublished review study by Benatti (2010), is planned to be divided in six parts. The different parts are as follows: (I) the species containing medullary norstictic and protocetraric acid (already published see Benatti 2012), (II) the species containing salazinic acid lacking vegetative propagules (this paper), (III) the species containing salazinic acid with vegetative propagules, (IV) the species containing fatty acids or no medullary substances, (V) the species containing the gyrophoric/lobaric/lecanoric acids lacking vegetative propagules, and (VI) the species containing the gyrophoric/lobaric/lecanoric with vegetative propagules, ultimately resulting in a synthesis of the whole genus followed by a world wide key.

The descriptions of the species treated here can also be found somewhere else in the literature such as Hale (1976a). Nonetheless, the present study includes detailed examinations (morphological and chemical) of all the type species; I mean the types of all the synonymous names under a species; details of basal bulb of the cilia including characteristics of oily substances; and detailed discussion. Additionally, I examined hundreds of specimens distributed world wide, which are not mentioned in previous studies. I found worth providing detailed species descriptions here because I found several specimens erroneously identified in dozens of herbaria including some at genus level, for example *Bulbothrix* specimens was identified as *Hypotrachyna, Parmelinella*

or *Parmelinopsis*. Perhaps, this could be due to short descriptions available in the literature that may lead to misinterpretation of species names or their characteristics. The review in this level of detail also aims to help as much as possible giving very detailed descriptions including fine morphological feature not elsewhere found on literature that might even help correlating with molecular data. This is not restrict for the species treated here, but to the whole genus, as all papers will aim to explain the peculiar problems regarding each species group.

Material and methods

Type material and additional specimens were studied from BM, FH, GLAM, H, HUFSCAr, LD, LG, M, NY, S, SP, TNS, TUR, US, W, and WU, originating from Asia, Africa, and South America. Added is a considerable material collected in Brazil during the last 30 years, mainly by the author and the members of the Lichenological Study Group of the Instituto de Botânica (GEL) in Brazil.

The methodology and conventions are detailed in Benatti (2012). Bulbs on cilia, rhizines, apothecia and other thallus parts were checked using the clarification method following Benatti (2011). Chemical constituents of the additional specimens examined were identified by thin-layer chromatography (TLC) using solvent C (Bungartz 2001), and compared with the data on labels left with the specimens. The chemical constituents of the types were examined by Prof. J. A. Elix (Canberra) using high performance liquid chromatography (HPLC), following the methods described in Elix et al. (2003).

The presence of salazinic acid is indicated by a K+yellow→dark red spot test reaction, not unlike that of norstictic acid, but turning darker red even with different KOH concentrations (10% and 30%) in *Bulbothrix* specimens. It also reacts P+ yellow, and does not react to C or KC, neither reacts to UV light. Its presence can also be indicated by the formation of bundles of thin elongated crystals of a deep reddish color, visible under a light microscope after the transfer of a small piece of the thallus or of the apothecia onto a microscope slide and dropping the reagent on the fungal material. However, as compared with the much more obvious crystals of norstictic acid (Benatti 2012), the crystals of salazinic acid need a higher concentration of the substance and take longer to crystallize.

The species selected for comparisons are those who show close morphological or chemical similarities, and those most often compared by other authors due to peculiar characteristics (e.g., Elix 1994, Divakar and Upreti 2005, Hale 1976a, Marcelli 1993, Sérusiaux 1984, Swinscow and Krog 1988). The species containing soredia, isidia and pustulae [*Bulbothrix australiensis* Hale, *B. decurtata* (Hale & Kurokawa) Hale, *B. imshaugii* (Hale) Hale, *B. isidiza* (Nylander) Hale, *B. microscopica* Elix, *B. pustulata* (Hale) Hale, *B. subglandulifera* (Hue) Hale, *B. subscortea* (Asahina) Marcelli & Benatti, *B. subtabacina* (Elix) Elix and *B. tabacina* (Montagne & Bosch) Hale] are the subject of a future treatment.

Results and discussion

The study confirmed all seven previously known species containing salazinic acid that do not form vegetative propagules or pustules. Four species, *Bulbothrix continua*, *B. linteolocarpa*, *B. sensibilis* and *B. setschwanensis* are corticolous, while *B. enormis* is saxicolous. *Bulbothrix hypocraea* and *B. meizospora* are predominatly corticolous, rarely saxicolous and in the case of *B. meizospora*, also rarely terricolous. All species are described in detail and discussed below.

Table 1 summarizes the main characteristics (usual averages found) used for differentiate the species in this paper and most commonly accepted in literature (see e.g. list in the Introduction).

Table 1. Comparative diagnostic characteristics of *Bulbothrix* species containing salazinic acid that do not reproduce by vegetative propagules. The data refer to the most typical range found.

Species	Laciniae width	Maculae	Marginal bulb size	Lower cortex color	Ascospore size
B. continua	1–2.5 mm	absent	ca. 0.05–0.15 mm wide	brown to pale brown	9.0–13.5 × 5.0–7.5 µm
B. enormis	1.5–8 mm	absent	ca. 0.05–0.20 mm wide	mostly pale brown	7.0–11.5 × 5.0–7.0 mm
B. hypocraea	1–2.5 mm	present (abundant)	ca. 0.10–0.30 mm wide	pale brown to ivory	7.0–14.0 × 5.0–8.0 mm
B. linteolocarpa	< 1 mm	absent	ca. 0.05–0.10 mm wide	pale brown	9.0–16.0 × 6.5–8.0 µm
B. meizospora	1.5–6 mm	present (weak)	ca. 0.10–0.30 mm wide	black center and most margins	10.0–22.0 × 7.5–14.0 µm
B. sensibilis	1.5–5 mm	present (variable)	ca. 0.05–0.25 mm wide	black center with brown margins	7.0–13.0 × 5.0–7.0 µm
B. setschwanensis	1–5 mm	absent	ca. 0.05–0.25 mm wide	pale brown center and margins	10.0–19.0 × 6.0–10.0 µm

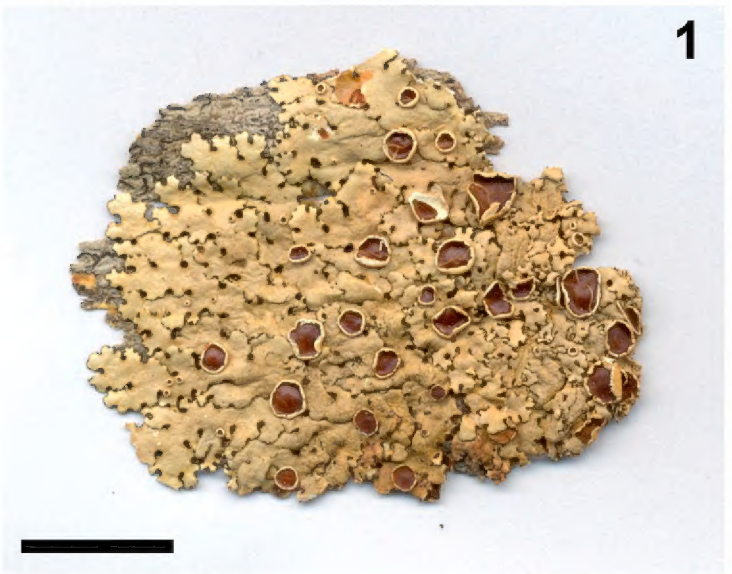
The species

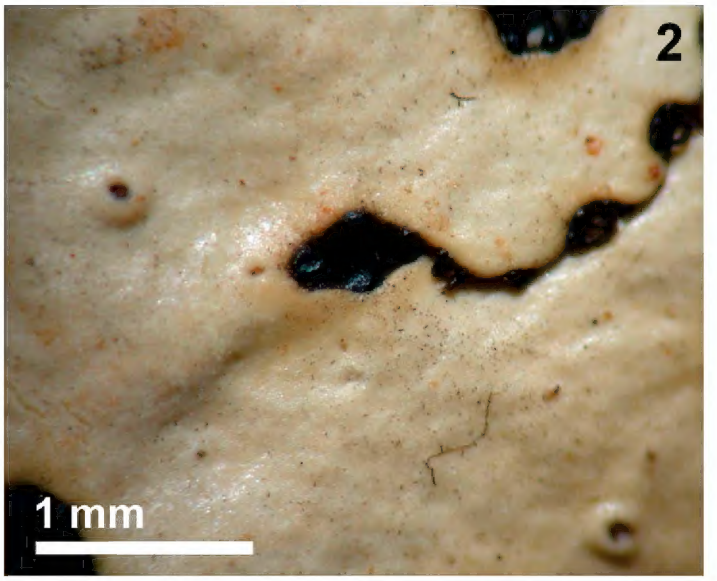
***Bulbothrix continua* (Lynge) Hale. Phytologia 28(5): 480. 1974.**
Mycobank: MB 341595
Figures 1–2

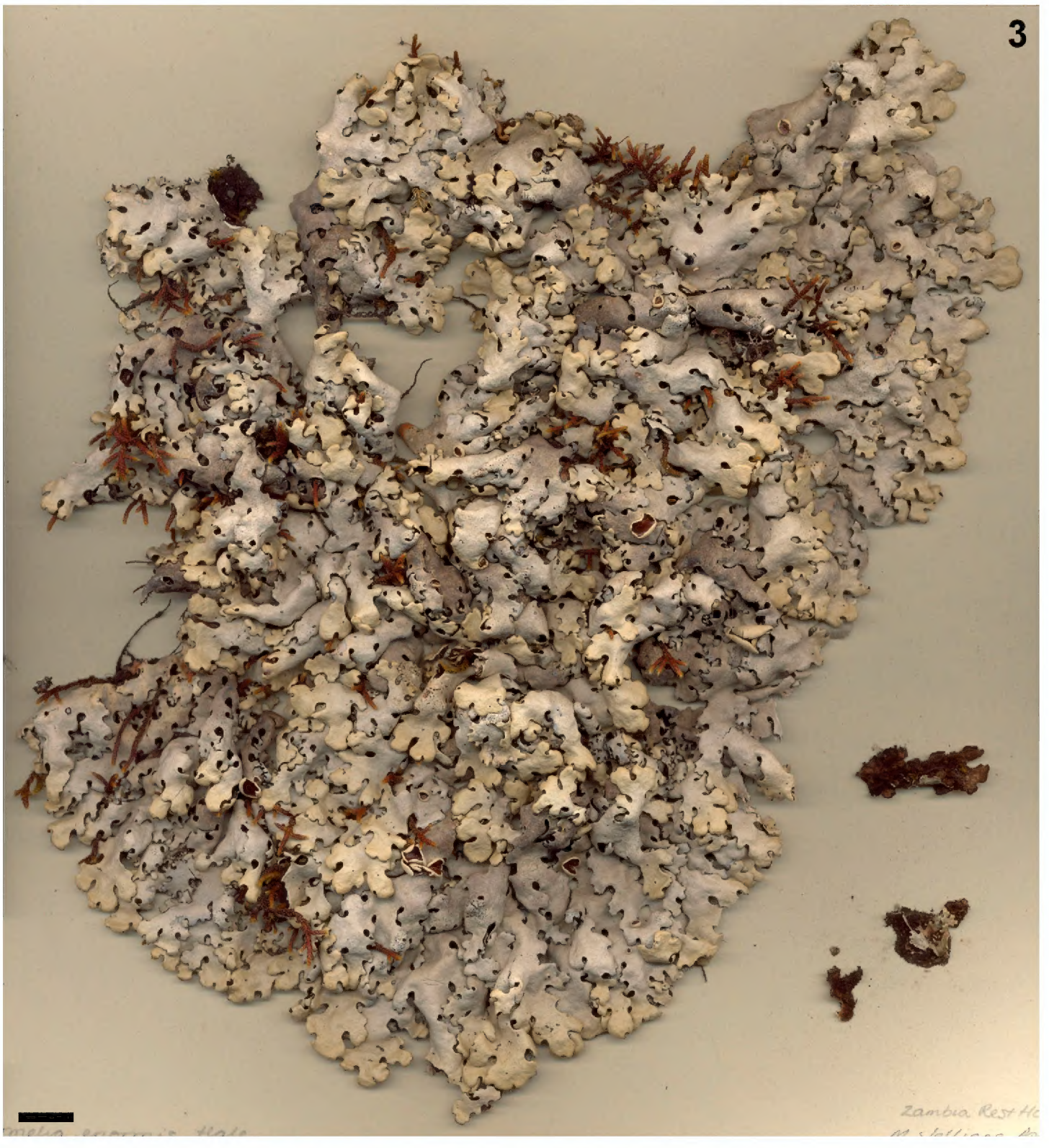
Basionym: *Parmelia continua* Lynge. Arkiv för Botanik 13(13): 109. 1914.

Holotype. Brasiliae civit Matto Grosso, Serra da Chapada, Buriti, leg. Malme s.n., 19-VI-1894 (S!).

Description. Thallus subirregularly laciniate, grayish green in the herbarium, up to 3.8 cm diam., subcoriaceous, corticolous; upper cortex 15.0–22.5 µm thick, algal layer 25.0–37.5 µm thick, medulla 67.5–85.0 µm thick, lower cortex 20.0–25.0 µm thick.







Figures 1–3. 1 Holotype of *Bulbothrix continua* **2** Detail of the shiny emaculate upper cortex **3** Holotype of *Bulbothrix enormis*. Scale bars = 1 cm (**1,3**), 1 mm (**2**).

Laciniae anisotomically to irregularly dichotomously branched, 0.8–1.9 (-2.3) mm wide, slightly imbricate, rarely becoming crowded at the center, adnate and adpressed, with flat, subtruncate apices; margins plane, smooth and sinuous to crenate, entire, occasionally sublacinulate; axils oval. Upper surface smooth and continuous, becoming rugose and irregularly cracked in some parts; laminal ciliary bulbs absent. Adventitious marginal lacinulae scarce and restrict to older parts, short, 0.2–0.5 × 0.1–0.5 mm, plane, simple to rarely furcate; apices truncate; lower side concolorous to the lower marginal zone. Maculae absent. Cilia black, without or with simple apices, commonly bent downwards, 0.05–0.40 × ca. 0.03 mm, with semi-immerse to emerse bulbate bases 0.05–0.15 (-0.25) mm wide, abundant throughout the margin spaced 0.05–0.10 mm from each other to contiguous, solitary or in small groups at the crenae and axils, scarce at the apices of the laciniae. Soredia, Pustulae and Isidia absent. Medulla white. Lower surface brown to pale brown, shiny to opaque, smooth to subrugose, weakly papillate, moderately rhizinate. Marginal zone brown to pale brown, indistinct from the center, shiny to opaque, smooth, weakly papillate, weakly to densely rhizinate. Rhizinae black to pale brown brown, partially white or with whitish apices when close to the margins, simple or sometimes irregularly branched, commonly with bulbate bases, 0.10–0.65 × 0.03–0.10 mm, frequent but becoming abundant close to the margins or scarce at some other parts, sometimes agglutinated, evenly distributed. Apothecia concave to plane or convex, adnate to sessile and distended over the laciniae, 0.4–3.7 mm diam., laminal; margin smooth to subcrenate, ecoronate; amphithecium smooth, without ornamentations. Disc pale brown, epruinose, imperforate; epithecium 15.0–20.0 mm high; hymenium 50.0–62.5 µm high; subhymenium 15.0–22.5 µm high. Ascospores ellipsoid to oval, 9.0–13.5 × 5.0–7.5 µm; epispore ca. 1.0 mm. Pycnidia common, laminal, immersed, with black ostioles. Conidia baciliform 5.0–7.5 × 1.0 µm.

TLC/HPLC: cortical atranorin, medullary salazinic and consalazinic acids (see also Hale 1976).

Distribution. South America: Brazil: State of Mato Grosso (Lynge 1914). Here is reported new for the Brazilian State of São Paulo.

Additional specimens examined. Brazil, Mato Grosso State, Santa Anna da Chapada, Buriti Municipality, leg. G. O. Malme s.n., 19-IV-1894 (US). Idem, São Paulo State, 6 km SW of Jaboticabal, 21°35'S, 48°35'W, on trees in "cerradão" (savannah), leg. A. Fletcher 10108, 1-V-1975 (BM). Idem, São Manuel Municipality, Fazenda Palmeira da Serra, unofficial private cerrado (savannah) reserve, on tree trunk in the cerrado, leg. M. P. Marcelli & S. B. Barbosa 35232, 03-VI-2003 (SP, paratype of *B. vainioi*). Idem, Santa Rita do Passa Quatro Municipality, Fazenda Vassununga, km 259 of Anhanguera Highway, 760 m, transition from cerrado to "cerradão" (savannah), trees with signs of old burns, on a tree thin twig, leg. M. P. Marcelli & S. B. L. Morretes 16055, 21-IX-1978 (SP). Idem, Moji-Guaçu Municipality, Fazenda Campininha, Estação Biológica de Moji-Guaçu, illuminated, dry savannah, on tree thin twig, leg. M. P. Marcelli 15885, 29-VI-1979 (SP).

Comments. The holotype (Figs 1–2) consists of a small, entire thallus, in good condition. The material contains several apothecia at different stages of maturity with well developed ascospores, and some pycnidia. It is on a small piece of tree bark but

with the laciniae apices free from the substrate, and is not glued to cardboard. There is no trace of true maculae in the upper cortex or in the amphithecia, although the cortex is in fact somewhat pale and shiny.

Hale (1960) mentioned that '*Parmelia*' *continua* was an unusual member of the section *Hypotrachyna* Vainio, without soredia or isidia and producing salazinic acid, believing at first that it might be a non-isidiate variety of '*Parmelia*' *cinerascens* Lynge. Latter, Hale and Kurokawa (1964) included '*P.*' *continua* in the key for the '*Parmelia*' species that composed the Subsection *Bicornutae* Series *Bicornutae*, separating '*P.*' *continua* from '*P.*' *hypocraea* Vainio by the absence vs. presence of cortical maculae, respectively.

Shortly after the recombination of '*Parmelia*' *continua* into *Bulbothrix* (Hale 1974), Hale (1976a) placed *B. continua* in the synonymy of *B. hypocraea* (Vainio) Hale, without any explanation. Most probably, Hale decided to synonymize them because of their great morphological similarity. However, I am inclined to accept Hale's first interpretation (1974), since the presence of maculae implies a fundamentally different anatomic conformation of the medullary hyphae, as observed by Barbosa and Marcelli (2010, 2011) in the genus *Parmotrema*.

Compared with the specimens of *B. continua*, those of *B. hypocraea* are always quite maculate, and their thalli often form wider laciniae than those of *B. continua*. Hale (1976a) mentioned that the discs of the apothecia in *B. hypocraea* have a burnt amber color. However, Marcelli (1993) cited a disc color, shape and distribution of cilia different than those described by Hale, more similar to *B. continua*.

Bulbothrix linteolocarpa Marcelli differs by the much narrower laciniae, barely exceeding 0.5 mm, that are also more linear with contiguous cilia forming long apices. As they mature, apothecia of *B. linteolocarpa* continually adapt to the conformation of the surface, settling on the laciniae as if they were spreading over them. Two specimens of uncertain identity cited by Marcelli (1993) among the examined material of *B. linteolocarpa* were actually found to be of *B. continua*.

Bulbothrix sensibilis (Steiner & Zahlbruckner) Hale differs from *B. continua* equally by the presence of cortical maculae and moreover by the shiny black lower cortex with dark brown margins. *Bulbothrix setschwanensis* (Zahlbruckner) Hale differs by the larger laciniae (ca. 1.5–5.0 mm wide) and by the size of the ascospores (usually 12.0–19.0 × 7.0–10.0 µm).

***Bulbothrix enormis* (Hale) Krog. The Lichenologist 25(3): 299. 1993.**
Mycobank: MB 360209
Figure 3

Basionym: *Parmelia enormis* Hale. Phytologia 23(4): 344. 1972.
Synonym: *Parmelina enormis* (Hale) Hale. Phytologia 28: 482. 1974.

Holotype. Zambia, Zambia Rest House area, Nyika Plateau, 7600 ft., on granite rocks, M. Jellicoe s.n., VII-1968 (BM!, isotypes at TNS n.v. and US!).

Description. Thallus sublinearly to subirregularly sublaciniate, gray with dusky green distal parts in herbarium, up to 24.1 cm diam., coriaceous, saxicolous; upper cortex 15.0–22.5 µm thick, algal layer 52.5–80.0 µm thick, medulla 120.0–150.0 µm thick, lower cortex 15.0–25.0 µm thick. Laciniae isotomically or anisotomically to irregularly dichotomously branched, (1.3–) 3.2–6.0 (–7.8) mm wide, imbricate to crowded, slightly to not adnate and loose, occasionally almost subcanaliculate, with involute to revolute or sometimes plane, subrounded to subtruncate apices; margins plane to subundulate or slightly involute, smooth and sinuous to occasionally subcrenate, entire, rarely little sublacinulate; axils oval. Upper surface smooth and continuous, rarely with some random irregular cracks; laminal ciliary bulbs absent. Adventitious marginal lacinulae scarce on random parts, short, 0.5–1.7 × 0.3–1.1 mm, usually involute, simple or sometimes irregularly branched; apices truncate to subtruncate; lower side concolorous to the lower marginal zone. Maculae absent. Cilia black to dark brown, with simple to partially double or furcate apices, occasionally bent downwards, 0.10–1.20 (-1.80) × ca. 0.05 (–0.10) mm, with semi-immerse to emerse bulbate bases 0.05–0.20 (-0.35) mm wide or partially not bulbate, sometimes disposed on a distinct black line, frequent to abundant throughout the margins, in small groups in the axils and adjacent parts spaced 0.10–0.40 mm from each other, becoming absent or scarce at the apices of the laciniae and adjacent parts. Soredia, Isidia and Pustulae absent. Medulla usually white, but pinkish in some random parts and below the hymenial discs. Lower surface pale brown, occasionally with random small dark brown or black spots, shiny, smooth, moderate to densely rhizinate. Marginal zone brown, indistinct from the center or sometimes interrupted by blackish spots, shiny, smooth, weakly papillate, gradually becoming rhizinate following the center. Rhizinae black to variably brown, occasionally whitish or with withish apices, simple to occasionally furcate or irregularly branched, without bulbate bases or with subtle basal or displaced bulbs, 0.20–1.80 (–2.30) × 0.05–0.10 mm, frequent to abundant, evenly distributed. Apothecia subconcave to urceolate or occasionally plane, becoming folded when old, adnate to substipiate, 1.1–10.0 mm diam., laminal to submarginal, ecoronate; margin smooth to subcrenate and fissured; amphithecium smooth, without ornamentations. Disc brown to dark brown, epruinose, imperforate; epithecium 7.5–17.5 µm high; hymenium 20.0–55.0 µm high; subhymenium 12.5–22.5 µm high. Ascospores ellipsoid to oval or subrounded, 7.0–11.5 × 5.0–7.0 mm; epispore (0.5–) 1.0–1.5 mm thick. Pycnidia laminal to submarginal, frequent, immerse, with brown or black ostioles. Conidia baciliform to weakly or distinct bifusiform 5.0–8.0 × 0.75 µm.

TLC/HPLC: cortical atranorin and chlororatranorin, medullary salazinic and consalazinic acids (see also Hale 1972, 1976b).

Distribution. Africa: Zambia (Hale 1972, 1976b, Krog 1993), Malawi, and Tanzania (Krog 1993).

Additional specimen examined. Zambia, Zambia Rest House area, Nyika Plateau, leg. M. Jellicoe s.n., IV-1969 (FH).

Comments. The holotype consists of a large specimen more than 20 cm in diameter, glued to board, in excellent condition and containing several apothecia and pyc-

nidia. There are some loose fragments from 3 to 10 cm diam., allowing vizualization of the lower cortex details. The isotype from US consists of several loose fragments such as those with the holotype, also in good condition, with mature apothecia and pycnidia. There are no remains of the rocky substrate of where the materials were collected, indicating that the thalli were not strongly adhered to the substrate.

Originally, Hale (1972) did not notice the presence of bulbs in the cilia of this species, and recombined it (Hale 1974) into *Parmelina* Hale without any comment. Hale (1972) first commented that the presence of cilia located in the axils would situate it in Section *Imbricaria*, even though he said that the species superficially resembled a *Hypotrachyna* species due the shape of the laciniae, what he again emphasized in the genus monograph (Hale 1976b). Although the general appearance of the thalli indeed resembles a large specimen of *Hypotrachyna* as he said, the presence of marginal cilia and the simple rhizines easily differentiate *B. enormis* from this other genus.

Most of the cilia seen in the specimens studied are bulbate, but some of them are not, even including some of the largest cilia. However, the bulbs have the typical anatomical structure of *Bulbothrix* species, with an oily substance and idioblasts cells (Hale 1975, Feuerer and Marth 1997, Benatti 2011). They vary from the more typical globose aspect to an oval shape, stretching following the growth and detachment of the apices. Some have slightly extended bases, perhaps an early stage of development of the cavity.

While Hale (1972, 1976b) mentioned an overall brown lower cortex, it should be noticed that although this is the predominant color, darker or even blackish spots may occur, occasional and randomly scattered (these were not seen in the FH specimen). The rhizines may also vary from paler to darker than the cortex, or be blackish.

Krog (1993) realized that this species did not fit well in the concept of the genus *Parmelina* due to the configuration of the lobes, and recombined it into *Bulbothrix*, having confirmed the presence of marginal bulbate cilia in the holotype and other specimens. The author realized that her material from Southern Africa fitted the description of *Parmelina enormis*, and she observed bulbate cilia in this species.

Bulbothrix hypocraea (Vainio) Hale and *B. setschwanensis* (Zahlbruckner) Hale were compared to *B. enormis* by Krog (1993) because they shared a pale brown lower cortex, simple rhizines and medullary salazinic acid. The author distinguished these species by their less robust thalli, usually adnate on bark, with crenate lobes with a more or less irregular pattern of branching. Besides the differences mentioned by Krog (1993), *B. hypocraea* also has narrower laciniae ca. 1.5–4.0 mm wide, an evidently maculate upper cortex, overall clearly bulbate cilia with short apices that appear solitary at the crenae and axils of the laciniae. *Bulbothrix setschwanensis* also differs by the narrower laciniae (ca. 1.0–3.5 mm wide), cilia in crenae or axilary with overall globose, evident bulbate bases and short apices, and by the larger ascospores (12.0–19.0 × 7.0–10.0 µm).

Bulbothrix haleana Sérusiaux (LG!, US!) differs by the thallus aspect, with narrow subirregular laciniae 1.0–3.5 mm wide, the overall globose and always evidently bulbate cilia with shorter apices, and by the smaller ascospores 5.0–9.0 × 4.0–7.0 µm. Further it contains norstictic acid, rather than salazinic acid as stated in the original description (Benatti 2012).

Another relatively similar species, *B. meizospora* (Nylander) Hale, also differs by the narrower laciniae (ca. 1.5–4.0 mm wide), larger ascospores (12.5–22.0 × 9.0–14.0 µm) and a black lower cortex with brown margins.

Hale (1972) compared *Bulbothrix enormis* also to *P. usambarensis* Steiner & Zahlbruckner [=*Pseudoparmelia usambarensis* (Steiner & Zahlbruckner) Krog & Swinscow (REN!, lectotype)], another similar African saxicolous species, but this species forms isidia, has a black lower cortex, and although he cited eciliate margins, it does have marginal cilia, just not in abundance.

***Bulbothrix hypocraea* (Vain.) Hale. Phytologia 28(5): 480. 1974.**
Mycobank: MB 341600
Figures 4–9

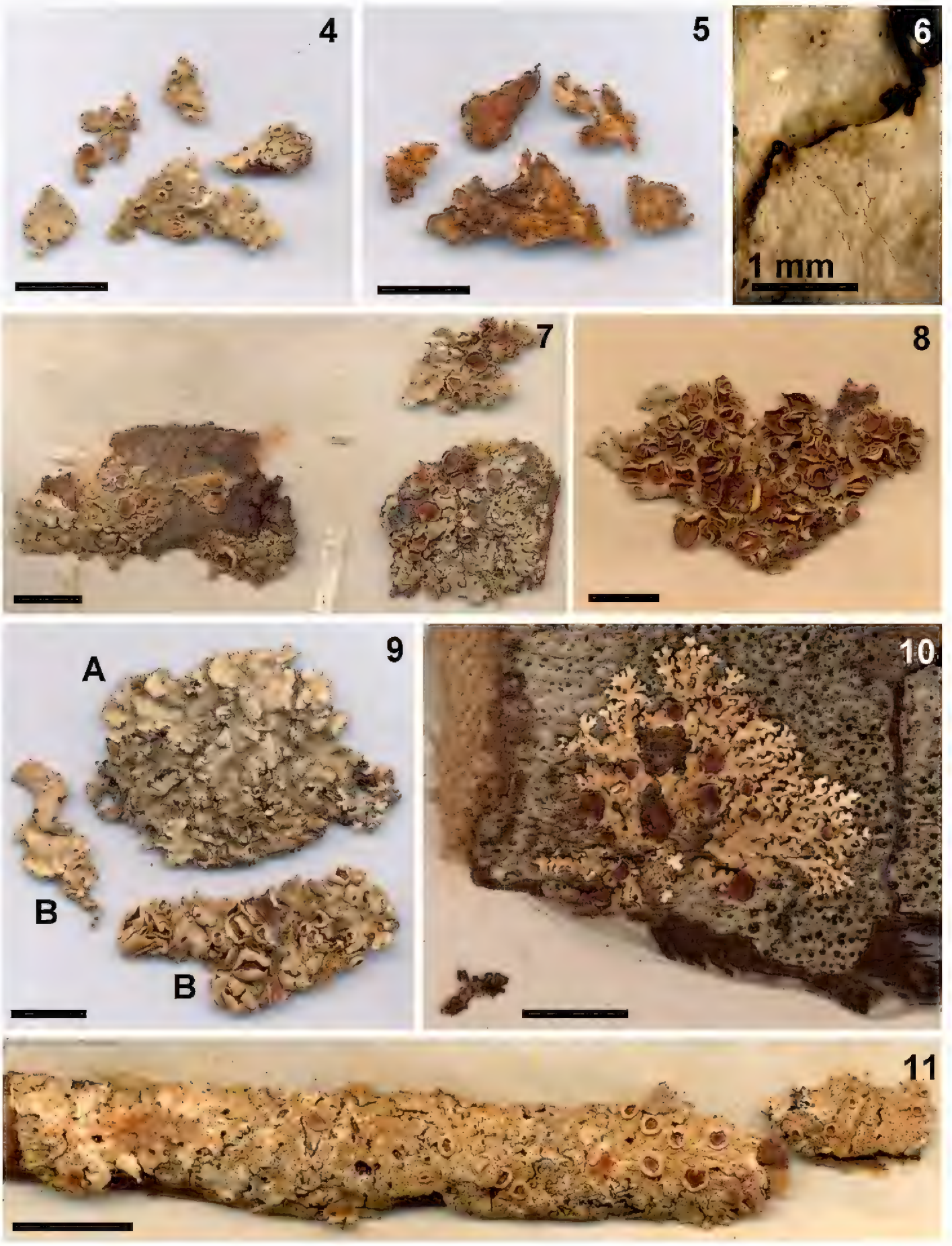
Basionym: *Parmelia hypocraea* Vainio. Catalogue of the African Plants Collected by F. Welwitsch 2(2): 400. 1901.

Synonyms: ? *Parmelia leptascea* Stein. & Zahlb. Botanische Jahrbücher für Systematik 60: 514. 1926.

Parmelia proboscidea var. *saxicola* Cengia Sambo. Nuovo Giornale Botanico Italiano 45: 380. 1938.

Lectotype. Angola, Huilla (3800 ad 5500 ped. s. m.), ad corticem arborum Leguminosarum in sylvis densis juxta flumen Monino, ca. 14°16°S, leg. Welwitsch 32 pro parte, IV-1860 (TUR-V!, duplicate at BM!).

Description. Thallus sublinearly to subirregularly laciniate to sublaciniate, light dusky gray in the herbarium, in fragments up to 5.2 cm diam., coriaceous to subcoriaceous, corticolous or rarely saxicolous; upper cortex 15.0–25.0 µm thick, algal layer 25.0–42.5 µm thick, medulla 75.0–125.0 µm thick, lower cortex 12.5–20.0 µm thick. Laciniae anisotomicaly dichotomously to irregularly branched, (0.5–) 0.9–2.6 (–3.0) mm wide, contiguous to slightly imbricate, rarely crowded at the center, ±adnate and loosely adpressed, with plane to slightly involute or revolute, truncate, subtruncate or subrounded apices; margins plane to subplane, smooth to sinuous and subcrenate or subirregular, entire to slightly incised, not lacinulate; axils oval to irregular. Upper cortex mostly continuous, occasionally with some irregular cracks on older parts, smooth to subrugose; laminal ciliary bulbs absent. Adventitious marginal lacinulae absent, even on old parts. Maculae usually distinct, puntiform to efigurate, laminal on the thallus or on the amphithecia of the apothecia. Cilia black or rarely brown, without or with simple apices, often bent downwards, 0.05–0.65 × 0.03–0.05 mm, with semi-immerse to emerse, bulbate bases (0.05-) 0.10–0.30 mm wide (these partially enlarged or occasionally absent), frequent throughout the margins, solitary or in small groups in the crenae and axils spaced 0.05–0.20 mm from each other to occasionally contiguous, becoming absent or scarce at the apices of the laciniae and adjacent parts, usually absent or scarce in the apices of the laciniae and adjacent



Figures 4–11. 4 Lectotype of *Bulbothrix hypocraea* **5** Detail of the lower side of the lectotype **6** Detail of the maculate upper cortex **7** Duplicate of *Bulbothrix hypocraea* **8** Holotype of *Parmelia leptascea* **9** Lectotype of *Parmelia proboscidea* var. *saxicola* (marked B) **10** Holotype of *Bulbothrix linteolocarpa* **11** Holotype of *Bulbothrix meizospora*. Scale bars = 1 cm (**4, 5, 7, 8, 9, 10, 11**), and 1 mm (**6**).

parts. Soredia, Isidia and Pustulae absent. Medulla white. Lower surface pale brown to ivory, opaque to slightly shiny, smooth, moderately rhizinate, sometimes up to the margins. Marginal zone indistinctly delimited from the center to slightly attenuate,

0.5–2.0 mm wide, pale brown to ivory, opaque to slightly shiny, smooth, weakly papillate, often rhizinate. Rhizinae ivory or light to dark brown, occasionally blackish, whitish or with white apices, simple or sometimes irregularly branched, partially with blackish bulbate bases or displaced bulbs, 0.10–0.80 (–1.10) × 0.05–0.10 mm, frequent, sometimes agglutinated, evenly distributed. Apothecia subconcave to subplane, becoming folded when old, sessile to adnate to substipiate, 0.3–8.2 mm diam., laminal to submarginal, ecoronate; margin subcrenate; amphithecia smooth occasionally fissured, without ornamentations. Disc pale brown to reddish brown, epruinose, imperforate; epithecium 7.5–17.5 µm high; hymenium 32.5–70.0 µm high; subhymenium 10.0–37.5 µm high. Ascospores ellipsoid to oval or subrounded, 7.0–14.0 × (5.0–) 6.0–8.0 mm; epispore ca. 1.0 mm. Pycnidia laminal, frequent mainly at the distal parts of the laciniae, immersed, with black ostioles. Conidia baciliform to weakly bifusiform (4.0–) 5.0–9.0 × 0.75 µm.

TLC/HPLC: cortical atranorin and chloroatranorin, medullary salazinic and consalazinic acids (see also Hale 1976).

Distribution. Africa (Zahlbruckner 1926): Angola (Vainio 1901, Hale 1976a), South Africa (Hale 1976a), Kenya, Tanzania (Sambo 1938, Swinscow and Krog 1988), Uganda (Hale 1976a, Swinscow and Krog 1988), Rwanda (Killmann and Fischer 2005, Bock et al. 2007), Rhodesia (nowadays Zimbabwe), Zaire, and Zambia (Hale 1976a). South America: Venezuela (López-Figueiras 1986, Marcano et al. 1996,) Brazil – States of Minas Gerais, Mato Grosso (Hale 1976a), Paraná (Eliasaro and Adler 1997, Eliasaro 2001), São Paulo (Hale 1976a, Marcelli 1993) and Tocantins (Eliasaro and Adler 1997).

Additional specimens examined. Africa, Bakoba am Victoriasee, auf Baumrinden, Schröder 319 (W!, holotype of *Parmelia leptascea*). Rhodesia (Zimbabwe), District Salisbury, Chindamora Reserve, Ngomakukira, epiphyte on *Julbernardia globiflora*, *Swatzia madagascariensis* etc., leg. H. Wild 5806, 10-VI-1962 (NY). Kenia, K4, Nth. Nyeri (1°30'S, 37°30'E), Lew Downs Ranch, 0 km W of Isiolo, Acacia woodland, leg. H. Ballev 660c, 4-XII-1981 (NY). Tanzania, Mahulo, Kipengere, loc. c. s. on rock, with *Usnea densirostra*, very mixed, leg. Eusébio 13 bis, 02-III-1935 (FI!, lectotype of *Parmelia proboscidea* var. *saxicola*, designate here as "B"). Brazil, Mato Grosso State, Serra do Roncador, riverine forest, 46 km north of Chavantina, Rio Vau, epiphyte, abundant, leg. G. T. Prance & N. T. Silva 59380A, 11-X-1964 (NY). Idem, Minas Gerais State, Lagoa Santa, leg. Warming s.n (M). Idem, São Paulo State, Brotas Municipality, NW side of intersectionof road to Campo Alegre with the Brotas-Itirapina road, arboreal semi-closed cerrado woodland, 22°17'S, 47°56'W, 750 m, leg. G. Eiten et al. 2976c, 16-VI-1961 (US). Idem, Santa Rita do Passa Quatro Municipality, fazenda Vassununga, km 259 of Anhanguera highway, on woody stem of vine, leg. M. P. Marcelli & B. L. Morretes 15628, 03-VI-1978 (SP). Idem, São Manuel Municipality, Fazenda Palmeira da Serra, non official particular cerrado (savannah) reserve, on tree trunk at the woods, leg. M. P. Marcelli & S. B. Barbosa 35680, 03-VI-2003 (SP).

Comments. The lectotype (Fig. 4–5) consists of three small fragments on bark glued to cardboard, and some smaller fragments packed in paper, free of substrate. The duplicate (Fig. 7) consists of three fragments, all on bark, one of them glued to cardboard (fragments free from substrate were used to see the features of the lower cortex). The type material has several pycnidia, restricted to the distal parts of the laciniae.

Bulbothrix hypocraea has the most strongly maculate thalli of the genus (Fig. 6). However, in very old herbalium material, such as the type, the maculae may become difficult to be see due to the darkening of the upper cortex and the staining of the medulla by the oxidized salazinic acid. In this case, a bright illumination and wetting the thalli make the maculae more visible.

Most cilia have an evident bulbate base, their apices are usually bent downwards and sometimes barely visible from above. Some cilia, however, have no basal bulb, but just a thickened, tapering base (possibly an early stage in the development of the cavity).

The color of the lower cortex varies from brown to ivory or cream, the marginal zone being slightly darker than the center (Fig. 5). The ivory color is the least common, and is similar to that observed in the lower margin of other Parmeliaceae (like *Parmotrema* species) which are white ivory when fresh, eventually changing color after time in the herbarium.

The swellings seen in the rhizines along its length are not actually endociliary pycnidia, as first suspected by Marcelli (1993), but basal or displaced bulbs. No conidia were found inside, but instead an oily substance like the one found in the marginal cilia. These structures have been noted already by Jungbluth (2006), who also called them bulbs. The color of the rhizines is somewhat variable, as in some thalli darker rhizines are commoner while in others these are of lighter tones. The bulbs are more difficult to see in blackish rhizines, since in this species they are usually thick.

Vainio (1901) mentioned a whitish color for the upper cortex (which suggests that the maculae of the type material were much more evident when the specimen was collected). He described the laciniae with a larger width (1.5–5.0 mm wide) than seen here. Hale (1976a) described *B. hypocraea* with a more similar laciniae shape, branching pattern and width (1–3.5 mm) like was seen here.

The ascospore measurements provided by Hale (1976a), Swinscow and Krog (1988), Marcelli (1993), Eliasaro (2001), and Jungbluth (2006) do not vary significantly and are in agreement with those of Vainio (1901) and those obtained here.

The description by Eliasaro (2001) has narrower laciniae compared to others (0.5–1.0 mm wide), but agrees in all other characteristics. Eliasaro reports occasional small amounts of norstictic acid in her specimens. This is probably contamination, since it was not reported by other authors and not found in the specimens studied.

Swinscow and Krog (1988) described African material of *B. hypocraea* that deviated by being emaculate or weakly maculate, with cilia often seen only as "black nodes" in the margins and with ascospores 8.0–10.0 × 3.0–5.0 mm, including some saxicolous specimens. From their perspective, it is close to the type of *Parmelia leptascea* Zahlbruckner and Steiner (W!). Unfortunately, this material was not sent on loan from O

for comparison, although requested several times. The authors present an illustration showing small cilia composed solely of the bulbs. Jungbluth (2006) supposed that these specimens might belong to a different taxon, for which the name *P. leptascea* might be available as seen here. Indeed no marginal cilia in the *P. leptascea* holotype (Fig. 8) have apices, even the most developed, usually restricted only to bulbs. These are also more abundant than those seen in typical specimens of *B. hypocraea*. However, besides the saxicolous habit, the laciniae usually crowded and with a larger maximum width, and the cilia aspect, no other significant differences were found with *B. hypocraea*, althought the maculae are evident despite the dark tone acquired in herbarium. The variations found may be merely due to the substrate. More material is needed for a decision about the status of this material and a proposition of a new combination regarding *Parmelia leptacea*.

The type collection of *Parmelia proboscidea* var. *saxicola* Cengia Sambo (FI!) consists of a ciliate *Parmotrema* specimen with submarginal, pustular soralia, and two fragments of *B. hypocraea* (Fig. 9, marked B) that make up the majority of the collection. Therefore the latter are appointed here as the lectotype, as it is in accordance to the species protologue. The comments of Cengia Sambo (1938) suggest that she did not realize that the parts were from two different species. The author did not describe the material in detail, only commenting that the laciniae were variable, the smaller thalli being so because of being saxicolous.

Bulbothrix setschwanensis (Zahlbruckner) Hale differs by the absence of cortical maculae and by larger ascospores 12.0–19.0 × 6.0–9.0 µm. Hale (1976a) distinguished this species from *B. hypocraea* in his key also by the width of the laciniae, but although there is a tendency for specimens of *B. setschwanensis* to have wider laciniae, there are specimens with laciniae the same width typically found in specimens of *B. hypocraea*, such as the holotype. Basically, the largest laciniae of *B. hypocraea* are of about the same width as the smallest of *B. setchwanensis*. The absence of maculae and the spore size are reliable characters to differentiate between the two species.

Bulbothrix linteolocarpa Marcelli was compared to *B. hypocraea* by Jungbluth (2006). It differs clearly by the much narrower linear laciniae 0.2–0.5 (–0.8) mm wide, by the emaculate upper cortex, and by the cilia with smaller bulbate bases and longer apices. The apothecia are also different in shape, being flatter and usually stretched over the laciniae.

Among other similar species, *Bulbothrix sensibilis* (Steiner & Zahlbruckner) Hale was compared to *B. hypocraea* by Hale (1976a) and Jungbluth (2006), and it differs by the black lower cortex with brown margins and by the weaker maculae of the upper cortex. *Bulbothrix subcoronata* (Müller Argoviensis) Hale (G!) was compared to *B. hypocraea* by Eliasaro (2001). The type material differs by a black lower cortex with brown margins, coronate apothecia containing smaller ascospores (5.0–7.5 × 4.0–5.5 mm) and medullary norstictic acid. *Bulbothrix meizospora* (Nylander) Hale was compared by Jungbluth (2006), and differs by the weaker maculae of the upper cortex, a black lower cortex with brown or black margins, and by the larger ascospores (12.0–22.0 × 9.0–14.0 µm).

***Bulbothrix linteolocarpa* Marcelli. Acta Botanica Brasilica 7(2): 42. 1993.**
Mycobank: MB 458790
Figure 10

Holotype. Brazil, Mato Grosso State, between Jaciara and São Vicente, km 313 of BR-364 highway, ca. 100 km ESE of Cuiabá, cerradão (savannah), on tree trunk, leg. Marcelli 8446, 2-VII-1980 (SP!).

Description. Thallus sublinear laciniate, dusky gray in the herbarium, up to 2.6 cm diam., subcoriaceous, corticolous; upper cortex 20.0–30.0 µm thick, algal layer 55.0–75.0 µm thick, medulla 25.0–35.5 µm thick, lower cortex 10.0–15.0 µm thick. Laciniae irregularly to anisotomically dichotomously branched, 0.2–0.6 (-0.8) mm wide, contiguous to occasionally slightly imbricate, adnate and adpressed, with flat, truncate apices; margins flat, smooth to sinuous or subirregular, entire to slightly incised and rarelly sublacinulate; axils oval to irregular. Upper cortex continuous, smooth to subrugose; laminal ciliary bulbs absent. Adventitious marginal lacinulae scarce on older parts, short, 0.1–0.6 × 0.05–0.20 mm, plane, simple; apices truncate; lower side concolor to the lower marginal zone. Maculae absent. Cilia black to brown, with simple to partially furcate apices, often bent downwards, 0.05–0.45 × ca. 0.03 mm, with semi- immerse to emerse bulbate bases ca. 0.05–0.10 mm wide, frequent along the margins, spaced 0.5–0.10 mm from each other rarely becoming contiguous at the axils, usually absent or scarce on the apices of the laciniae. Soredia, Isidia and Pustulae absent. Medulla white. Lower surface pale brown, shiny, smooth, weakly papillate, moderately rhizinate. Marginal zone pale brown, slightly darker than the center, shiny, attenuate, 0.5–1.0 mm wide, smooth, weakly papillate, sligthly rhizinate. Rhizinae light to dark brown or almost blackish, simple to occasionally furcate or irregularly branched, often with dark basal or displaced bulbs, 0.05–0.60 × ca. 0.03–0.05 mm, frequent, becoming scarce at some parts, partially agglutinated, evenly distributed. Apothecia subconcave, becoming plane or convex, stretching over the laciniae while maturing, adnate, 0.3–3.4 mm diam., laminal, ecoronate; margin smooth to incised and subcrenate; amphitecium smooth, without ornamentations. Disc brown, epruinose, imperforate; epithecium 12.5–20.0 mm high; hymenium 37.5–45.0 µm high; subhymenium 15.0–20.0 µm high. Ascospores ellipsoid to oval, (9.0–) 10.0–16.0 × 6,5–8,0 µm; epispore ca. 1.0 µm. Pycnidia not found.

TLC/HPLC: cortical atranorin and chloroatranorin, medullary salazinic, consalazinic and secalonic A acids (label from J. A. Elix with the holotype, 19-VII-1995).

Distribution. South America. Brazil – States of Mato Grosso and São Paulo (Marcelli 1993).

Additional specimens examined. Brazil, Mato Grosso State, between Jaciara and São Vicente, ca. 100 km ESSE of Cuiabá, 750 m alt., on thin twig at the cerrado (savannah), leg. M.P. Marcelli 8445, 02-VII-1980 (SP). Idem, São Paulo State, Moji-Guaçu Municipality, Fazenda Campininha, Estação Biológica de Moji-Guaçu, illuminated and dry cerradão (savannah), on thin twig, leg. M.P. Marcelli 15812, 07-XII-1976 (SP). Idem, Santa Rita do Passa Quatro Municipality, fazenda Vassununga,

km 259 of the Anhanguera Highway, 760 m alt., transition from cerrado to cerradão (savannah), trees with signs of old burnings, on tree thin twig, leg. M.P. Marcelli & SB. L. Morretes 15626, 23-VI-1978 (SP). Idem, São Carlos Municipality, Campus of the Universidade Federal de São Carlos - UFSCar, cerrado (savannah), on a wooden fence near a firebreak, 22°1'S, 47°53'W, alt. 855 m, on *Eucalyptus* sp. trunk, leg. G. G. Batista & M. N. Benatti 115B, 04-IX-2006 (HUFSCar).

Comments. The holotype (Fig. 10) consists of small thalli about 2.5 cm diameter, in good condition, on tree bark and over a crustose lichen with blackened perithecia. It was necessary to detach some laciniae for proper observation of the lower cortex. The upper cortex is emaculate, and there are several apothecia with ascospores in different stages of maturation.

A peculiar anatomical characteristic is that the algal layer is always thicker than the medulla in all examined material of *B. linteolocarpa*, and usually appears to be in the middle of the medulla, separating it in two portions, instead of being situated in its upper portion just below the cortex.

Some of the specimens analysed by Marcelli (1993) were confirmed to have wider laciniae (1.0–2.5 mm), a darker brown lower cortex, cilia with very globose basal bulbs and longer apices, and simple rhizines simply without basals bulbs. These specimens, that the author suspected to belong to a similar but different taxon, are actually *B. continua* (Lynge) Hale.

Bulbothrix continua (Lynge) Hale is the closest species to *B. linteolocarpa* in overall characteristics. However, *B. linteolocarpa* has much narrower laciniae than *B. continua* (0.2–0.5 against 1.0–2.5 mm), cilia with smaller, less globose bulbate bases (0.05–0.10 mm vs. 0.05–0.25 mm), and always with apices that are also partially furcate, a darker lower cortex, and less abundant, more variably branched rhizines.

Marcelli (1993) compared *B. linteolocarpa* to *B. hypocraea* (Vainio) Hale and to *B. sensibilis* (Steiner & Zahlbruckner) Hale. As to *B. hypocraea*, see under that species. *Bulbothrix sensibilis* has larger laciniae (ca. 1.0–4.0 mm larg.) that are often imbricated or crowded, cilia without apices or with simple short apices, normally restricted to the crenae and axils of the laciniae, concave to urceolate apothecia, a black lower cortex with brown margins, and averagely smaller, often subrounded ascospores (7.0–12.0 × 5.0–7.0 µm).

An apparently common species on cerrado (savannah) areas, *Bulbothrix linteolocarpa* was mentioned by Mistry (1998) in an article on bioindicators of fires.

Bulbothrix meizospora **(Nyl.) Hale. Phytologia 28(5): 480. 1974.**
Mycobank: MB 341605
Figures 11–14

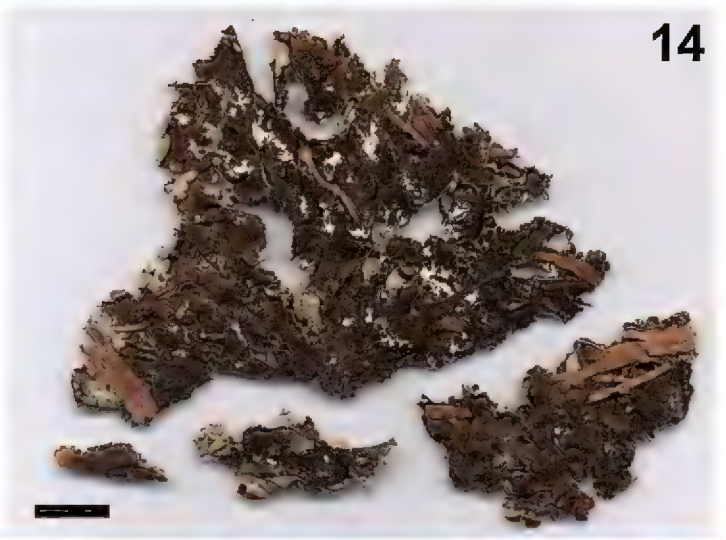
Basionym: *Parmelia tiliacea* var. *meizospora* Nyl. Synopsis Methodica Lichenum 1: 383. 1860.
Synonyms: *Parmelia meizospora* (Nylander) Nyl. Flora 52: 292. 1869.

Parmelia amplectens Stirton. Scottish Naturallist 4: 201. 1878.
Bulbothrix vainioi Jungbluth, Marcelli & Elix. Mycotaxon 104: 59. 2008.

Holotype. India, Nilgherries Montains, Watt s.n. (H-NYL 35107!).

Description. Thallus subirregular laciniate to sublaciniate, dark dusky gray in the herbarium, up to 7.3 cm diam., subcoriaceous to submembranaceous, corticolous (rarely on rocks or soil); upper cortex 15.0–20.0 µm thick, algal layer 25.0–35.0 µm thick, medulla 85.0–110.0 µm thick, lower cortex 15.0–20.0 µm thick. Laciniae irregularly to almost anisotomically dichotomously branched, 1.6–6.1 mm wide, contiguous to slightly imbricate, becoming crowded at the center, ±adnate and adpressed, with flat to slightly involute, subrounded to subtruncate or rarelytruncate apices; margins flat to slightly involute, crenate to or irregular, entire, rarely sublacinulate; axils oval to irregular. Upper cortex smooth and continuous at younger parts, becoming rugose and irregularly cracked at older parts; laminal ciliary bulbs absent. Adventitious marginal lacinulae absent to scarce on older parts, short, 0.2–0.8 × ca. 0.1–0.3 mm, plane, simple; apices truncate; lower side concolorous with the lower marginal zone. Maculae weak, punctiform, laminal or in the amphithecium, usually common but hard to see on darkened specimens (such as the type). Cilia black, without or with simple or double apices, short and bent downwards, 0.05–0.30 (–0.60) × 0.03–0.05 mm, with semi-immerse to emerse bulbate bases 0.10–0.30 mm wide (these partially enlarged or occasionally absent), often withered and becoming reniform at the axils, scarce along the margins but more frequent at the crenae and axils, spaced 0.05–0.15 mm from each to occasionally contiguous, solitary or in small groups, becoming absent at the apices and adjacent parts of the laciniae. Soredia, Isidia and Pustulae absent. Medulla white. Lower cortex black, occasionally dark brown at the transition from the margins to the center, slightly shiny to opaque, smooth to rugose, moderately rhizinate. Marginal zone black and indistinct from the center to brown or dark brown and attenuate, 0.5–4.0 mm wide, opaque to slightly shiny, smooth to rugose, weakly papillate, scarcely rhizinate at the transition to the center. Rhizinae black, occasionally dark brown close to the margins, initially simple to rarely furcate, without basal or displaced bulbs, 0.10–0.40 (–0.70) × ca. 0.05 mm, usually frequent but varying from scarce to abundant at a few parts or near the margins, evenly distributed. Apothecia urceolate to concave or subconcave, partially becoming fissured and folded when old, adnate to subpedicelate, 0.8–6.2 mm diam., laminal to submarginal, ecoronate; margin smooth; amphitecia smooth becoming subrugose, without ornamentations. Disc light to dark brown, epruinose, imperforate; epithecium 10.0–20.0 µm high; hymenium 50.0–80.0 µm high; subhymenium 15.0–37.5 µm high. Ascospores ellipsoid to oval or rounded, (10.0–) 12.5–19.0 (–22.0) × (7.5–) 9.0–11.0 (–14.0) µm; epispore (0.5–) 1.0–1.5 µm. Pycnidia frequent, laminal to submarginal, immerse, with black ostioles. Conidia baciliform to weakly or distinctly bifusiform (4.0–) 5.0–9.0 × 0.75 µm.

TLC/HPLC: cortical atranorin and chloroatranorin, medullary salazinic and consalazinic acids (see also Hale 1976).



Figures 12–16. 12 Lectotype of *Parmelia amplectens* **13** Holotype of *Bulbothrix vainioi* **14** Detail of the lower cortex of *B. vainioi* **15** Holotype of *Bulbothrix sensibilis* **16** Holotype of *Bulbothrix setschwanensis*. Scale = 1 cm (**14, 15, 16**), 2 mm (**17**), 1 mm (**18**), and 20 µm (**19**).

Distribution. Asia: India (Nylander 1860, Stirton 1878, Hale 1976a, Divakar and Upreti 2005), Pakistan (Hale 1976a), Nepal (Hale 1976a, Kurokawa 1993), and Thailand (Wolseley et al. 2002). Africa: Camarões (Hale 1976a), Kenya (Swinscow and Krog 1988), and Tanzania (Krog 2000). South America: Brazil - State of São Paulo (Marcelli 1993, Jungbluth 2006). Accordingly to Elix (1994), the species was erroneously cited for Australia (Knight 1882), and does not occur in that region. Here it is cited as new for Malawi.

Additional specimens examined. India, Mussoorie, northwest Himalaya, 7000 ft., leg. R. R. Stewart s.n., VII-1931 (NY 12298). Idem, Nilgherries Montains, *Watt* s.n. (lectotype of *Parmelia amplectens*, BM!, duplicate at GLAM!). Pakistan, Lower Topa, Murree hills, on bark of Pinus excelsa, leg. S. H. Iqbal 835, 11-VII-1967 (US). Malawi, Cholo Mt., dead branchlets of rain-forest trees, 1200 m alt., leg. L. J. Brass s.n. 24-IX-1946 (NY 17788). Brazil, São Paulo State, Itirapina Municipality, Estação Experimental de Itirapina, IF, leg. P. Jungbluth, L. S. Canêz & A. A. Spielmann PJ881, 26-III-2004. Idem, Santa Rita do Passa Quatro Municipality, Fazenda Vassununga, km 259 of the Anhanguera Highway, leg. M. P. Marcelli & B. L. Morretes 15653, 03-VI-1978 (SP). Idem, São Manuel Municipality, Fazenda Palmeira da Serra, non official particular cerrado (savannah) reserve, on tree trunk, leg. M. P. Marcelli & S. B. Barbosa 35693, 03-VI-2003 (SP). Idem, Botucatu Municipality, beside the highway that connects the city to the highway Castello Branco (SP-280), km 3, private cerradão forest inside Fazenda Morro do Ouro, 22°53'S, 48°26'W, 804 m alt, on a tree trunk, leg. M. P. Marcelli & S. B. Barbosa 35696, 4-VI-2003 (holotype of *Bulbothrix vainioi*, SP!).

Comments. The holotype (Fig. 11) consists of a single thallus on bark. It is partially detached from the substrate and in poor condition. Part of the upper cortex is absent, the medulla is much stained by oxidized salazinic acid, and the thallus is brittle and fragile. There are several apothecia in different stages of maturation, some of them also damaged, though they have ascospores. The thallus has many pycnidia, some containing conidia.

Nylander wrote on a label with the type specimen voucher "ascospores 14.0–18.0 × 7.0–11.0 mm", but mentioned as measures 14.0–21.0 × 8.0–11.0 mm at the work in which he described *Parmelia tiliacea* var. *meizospora* (Nylander 1860), and as 11.0–21.0 × 8.0–11.0 mm in the work that raised the variety to the rank of species (Nylander 1869).

Nylander (1885) mentioned bifusiform conidia for Indian material, measuring 5.0 × 0.5–0.7 µm (he was one of the first authors to note bifusiform conidia in *Bulbothrix*). Divakar and Upreti (2005) and Jungbluth (2006) also mentioned bifusiform conidia for *B. meizospora*.

Hale (1976a) mentioned that the size of ascospores was variable in the species, and that is confirmed by the material cited below, in which ascospores may have any measure starting from 12.0–15.0 × 7.0–10.0 µm up to 12.0–22.,0 × 8.0–12.,0 µm. Marcelli (1993) and Jungbluth (2006) mentioned ascospores 12.0–16.5 × 8.0–10.0 µm. Ascospores under 12.0 µm are usually quite rare and look not fully developed.

Cilia in *B. meizospora* are usually infrequent, and a portion of them in a same thalli apices might not present apices, while some others do not have bulbs. Often the bulbs become withered or reniform, which is more evident in the axillary cilia.

Regarding the presence and intensity of cortical maculae, Swinscow and Krog (1988) and Marcelli (1993) cited specimens of *B. meizospora* with absence of cortical macules, while Hale (1976a) and Divakar and Upreti (2005) mentioned that the species can be weakly to moderately maculate, and Jungbluth (2006) mentioned distinct maculae.

Apparently, as mentioned by Benatti (2010), there are no *Bulbothrix* species with varaible presence of maculae, but that are are always either emaculate such as *B. continua* (Lynge) Hale, or always maculate as *B. hypocraea* (Vainio) Hale. What seems to happen is that certain species, such as *B. meizospora*, have variable maculae intensity, more subtle and scarce in some thalli (which makes it difficult to see them) and somewhat more evident in others.

Bulbothrix setschwanensis (Zahlbruckner) Hale was compared to *B. meizospora* by Hale (1976a) and Divakar and Upreti (2005). It differs by the more constantly bulbate cilia with distinct apices that appear more abundantly at the margins, and by the pale brown lower cortex.

Bulbothrix sensibilis (Steiner & Zahlbruckner) Hale was compared by Swinscow and Krog (1988), and differs from *B. meizospora* only by the smaller ascospores, which vary from 7.0–9.0 × 4.0–7.0 to 8.0–12.0 × 6.0–8.0 mm, as cited by Zahlbruckner (1926), Hale (1976a), and Swinscow and Krog (1988) and as seen in the present work. Hale (1976a) used the laciniae aspect and width to differentiate the species, I found that these features are not very helpful in the case of these two species, with only the tendency of smaller sizes to be more common in *B. sensibilis*. Although Hale (1976a) used the shape and width of the laciniae for differentiation, comparisons between *B. sensibilis* and *B meizospora* gave almost identical measurements, with slight variations in width, the specimens of *B. sensiblis* frequently tending to have narrower, more often sublinear laciniae. Besides the sole significative difference of ascospore sizes, recent analyses of DNA sequences corroborate the distinction of the species (Divakar et al. 2010).

Bulbothrix hypocraea (Vainio) Hale was compared to *B. meizospora* by Jungbluth (2006). It differs by having a distinctly maculate upper cortex, narrower and sublinear laciniae (ca.1.0–3.0 mm wide), a pale brown lower cortex and smaller ascospores (usually 7.0–14.0 × 5.0–8.0 µm).

Recognition of *B. meizospora* as a *Bulbothrix* species can sometimes be difficult, as commented already by Marcelli (1993), due to the relatively large size of the thalli when compared to other species of the genus, and because the bulbs are not very evident in the cilia or sometimes partially absent. Notably *Canoparmelia amazonica* (Nylander) Hale, present in the same habitats, was compared by Marcelli (1993) to *B. meizospora*, suggesting that in certain circumstances they could be mistaken in field. *Canoparmelia amazonica* can be distinguished by the complete absence of marginal cilia and by the presence of medullary protocetraric acid.

The type material (Fig. 12) of *Parmelia amplectens* Stirton (BM! lectotype, GLAM! duplicate) has cilia with more distinct bulbs and somewhat longer apices, and it is difficult to recognize maculae due its poor condition. However, the further characteristics agree with those of *B. meizospora* as accepted by Hale (1976a). Stir-

ton (1878) described ellipsoid ascospores 15.0–18.0 × 9.0–12.0 µm and cylindrical straight conidia 6.0 × 0.7 µm, which are also in agreement with measurements obtained here from the type (ascospores 12.0–19.0 × 10.0–12.0 µm; conidia nearly identical) and those normally found in *B. meizospora*. The lectotype is a relatively large thallus (about 10 cm wide) in poor condition, the cortex and several of the marginal ciliary bulbs badly damaged. It is less brownish than the duplicate, but also with the medulla stained by oxidized salazinic acid, and several apothecia have lost their hymenia. The duplicate is composed of two larger fragments a few cm wide and several smaller fragments, and it is very dusky brown.

Bulbothrix vainioi (Fig. 13–14) Jungbluth, Marcelli and Elix was described by Jungbluth et al. (2008) based on specimens with ascospores over 12 µm long included by Hale (1976a) provisionally in *B. sensibilis*. However, apparently they overlooked the possibility that their material could belong to *B. meizospora*, the ascospores with the minimum common diameter for that species. As was checked here, all specimens assigned to *Bulbothrix vainioi* are morphologically identical with *B. meiospora* and have the same chemistry. Consequently *Bulbothrix vainioi* is not a species similar to *B. sensibilis* with larger ascospores, as the authors assumed, but typical *B. meizospora* with ascospores 12.0–16.0 µm long, a size range well inside the limits found for this species, and with the same cilia.

Hale (1976a) and Divakar and Upreti (2005) mentioned that thalli of *B. meizospora* can occasionally be found on rocks, and rarely on soil. Divakar and Upreti (2005) mentioned pycnidia usually confined to peripheral areas of laciniae, but in the holotype and other material studied they can be seen all over the thallus.

***Bulbothrix sensibilis* (Stein. & Zahlb.) Hale. Phytologia 28: 481. 1974.**
Mycobank: MB 341612
Figure 15

Basionym: *Parmelia sensibilis* Stein. & Zahlb. Afrikanische Flechten (Lichenes), Englers Botanische Jahrbücher für Systematik 60: 522. 1926.

Holotype. British East Africa, Bei-Bura (Kenia), auf Baumzweigen, leg. Schröder 285 (W!).

Description. Thallus subirregularly to sublinearly sublaciniate, dusky gray in the herbarium, up to 6.9 cm diam., subcoriaceous, corticolous or ramulicolous; upper cortex 12.5–25.0 µm thick, algal layer 15.0–27.5 µm thick, medulla 87.5–120.0 µm thick, lower cortex 12.5–17.5 µm thick. Laciniae irregularly to occasionally anisotomically dichotomously branched, 1.3–5.2 mm wide, slightly imbricate, becoming crowded at the center, weakly adnate and loosely adpressed, with flat, subrounded to subtruncate apices; margins flat, slightly sinuous to crenate or irregular, entire to slightly incised, ocasionally sublacinulate; axils oval to irregular. Upper cortex smooth and continuous, becoming subrugose with occasional irregular cracks only on older parts; laminal ciliary bulbs absent. Adventitious marginal lacinulae scarce on older parts, short, 0.2–1.2

× 0.1–0.2 mm, plane, simple to irregularly branched; apices truncate; lower side concolor with the lower marginal zone. Maculae weak to distinct, puntiform, laminal, more evident at distal parts of the thallus. Cilia black, without or with simple and short apices, occasionally bent downwards, 0.05–0.20 (–0.30) × ca. 0.03 mm, with emerse bulbate bases 0.05–0.25 mm wide, occasionally withered and reniform, scarce along the margins, becoming frequent at the crenae and axils spaced ca. 0.05–0.15 mm from each other to eventually contiguous, solitary or in small groups becoming absent or scarce at the apices and adjacent parts of the laciniae. Soredia, Isidia, and Pustulae absent. Medulla white. Lower cortex black, with random dark brown spots at the transition to the center, slightly shiny, smooth to subrugose or subvenate, moderately rhizinate. Marginal zone mostly brown, attenuate, ca. 0.5–2.0 mm wide, partially black and indistinct from the center, slightly shiny, smooth to subvenate, weakly rhizinate until the transition to the center. Rhizinae black, sometimes partially dark brown close to the margins, simple to rarely furcate, without basal or displaced bulbs, 0.10–0.30 (-0.40) × ca. 0.05 mm, usually frequent but scarcer at the margins and at the transition to the center, evenly distributed. Apothecia concave to subplane, sessile to adnate, 0.2–4.3 mm diam., laminal, ecoronate; margin and amphitecia initially smooth becoming subrugose, without ornamentations. Disc pale brown, epruinose, imperforate; epithecium 10.0–17.5 µm high; hymenium 30.0–47.5 µm high; subhymenium 20.0–30.0 µm high. Ascospores ellipsoid to oval, (7.0–) 8.0–12.0 (–13.0) × 5.0–7.0 µm; epispore ca. 0.75 µm. Pycnidia frequent, laminal, immersed, with black ostioles. Conidia baciliform to weakly bifusiform 5.0–9.0 × 0.75 µm.

TLC/HPLC: cortical atranorin, medullary salazinic and consalazinic acids (see also Hale 1976).

Distribution. Asia: Sri Lanka (Awasthi 1976), India (Awasthi 1976, Divakar and Upreti 2005), and Thailand (Pooprang et al. 1999); África: Kenya (Zahlbruckner 1926, Dodge 1959, Swinscow and Krog 1988), Tanzania (Swinscow and Krog 1988), Angola, Guinea, Malawi, Zaire, Zambia (Hale 1976a), Madagascar (Aptroot 1990), and Rwanda (Killmann and Fischer 2005, Bock et al. 2007); South America: Venezuela (Hale 1976a, López-Figueiras 1986), Brazil - State of São Paulo (Marcelli 1993).

Additional specimens examined. Venezuela, Táchira, Via Rubio, Brámon, 800–1100 m, leg. M. E. Hale & M. López Figueiras 45727, 24-III-1975 (US). Brazil, São Paulo State, 6 km SW of Jaboticabal, 21°35'S, 48°35'W, on trees in cerradão, leg. A. Fletcher 10138, 03-V-1975 (BM). Idem, Pirassununga, Rawitscher Reserve, Cerrado auf Zweigen, leg. H. Walter & E. Walter Br 58, 30-IX-1965 (M).

Comments. The holotype of *B. sensibilis* (Fig. 15) consists of a small thallus ca. 6.0 cm in diameter on tree branch, in a reasonable state of preservation, although several parts and apothecia are badly damaged. The material is glued to the card voucher, and it was necessary to free some laciniae for observation of the lower cortex. There are apothecia containing ascospores in good condition and there are several pycnidia with conidia.

Steiner and Zahlbruckner (Zahlbruckner 1926) described the species as having no cilia, but mentioning of what they interpreted as a constant presence of parasites with inflated bases or converted into bulbs ("non rare planta parasitica inclusis, basin ver-

sus semel vel bis bulbiformiter inflatis vel bulbum tantum formantibus"). The authors also noted the occurrence of brown patches in certain parts of the center of the thallus lower cortex, and not just at the margins. Dodge (1959) commented on the tendency of laciniae in the central parts of the thalli to became with a more wrinkled and broken surface. The author also did not perceive the bulbate cilia, though he did mention something like small papillate rhizines along the margins. Interestingly, he described the apothecia as perforate, what was not found on the material examined here. Awasthi (1976) was the first author to describe bulbate cilia for the species. The characteristics he described are in accordance with the type material, only his measures of the laciniae being even wider (2.0 to 6.0 mm). The ascospore descriptions and measurements of the specimens studied by Dodge (1959), Awasthi (1976), Swinscow and Krog (1988) and Divakar and Upreti (2005) are all in accordance with the type of material of *B. sensibilis*.

The material atributted by Marcelli (1993) to *B. sensibilis*, described as emaculate with a overall black lower cortex, sparse rhizines sparse and ascospores 12.6–14.4 × 7.2–8.1 µm are in fact weakly, sparsely maculate specimens of *B. meizospora* with laciniae and ascospore of minimum dimensions found in the species, but not below those considered normal.

Hale (1976a) attributed examined specimens from several African countries and Venezuela to *Bulbothrix sensiblis*, with a first citation of the species for the Americas. Overall, the material described is in accordance with the type material. However, in two keys (Hale and Kurokawa 1964, Hale 1976a) were cited ascospores sizes as 7.0–9.0 µm long, much smaller than the size 7.0–18.0 × 5.0–12.0 µm that Hale mentioned in the description of the species in his monograph (Hale 1976a).

Hale (1976a) cited in his key subirregular laciniae for *B. meizospora* and sublinear for *B. sensibilis,* the opposite of what is in his descriptions, where *B. meizospora* is the species described as having sublinear laciniae, not *B. sensibilis*. Although he used different widths in the key laciniae as to differences for separate them, he also described the same size for both. Jungbluth et al. (2008) discussed in the description of *B. vainioi* on the possible identity of the South American material of *B. sensibilis* seen by Hale (1976a). The authors believed in the hypothesis of the involvement of two taxa, one composed of African and Indian specimens with ascospores less than 12.0 µm long corresponding to the true *B. sensibilis*, and the other composed of the South American specimens with ascospores larger than 12.0 µm long that they described as *B. vainioi*.

It is possible that Hale (1976a) may have been confused when typing measurements closer to those of the ascospores of *B. meizospora* in the description of *B. sensibilis*, since the differences he used in the key are exactly as seen here. Another hypothesis is that Hale may have mistaken the material of Venezuela with *B. sensibilis* due to the similarity between the African specimens with his South American specimen. As found by analyzing material of *B. vainioi* and *B. meizospora*, even differences of cilia cited in the comments under *B. vainioi* are minimal and usually found in the same species, even in a same specimen.

Bulbothrix hypocraea (Vain.) Hale differs by being more evidently maculate than *B. sensibilis*, by the pale brown lower cortex with slighly darker margins, and by the

brown rhizines with dark basal or displaced bulbs. Hale (1976a) noted that although the african-american pattern of distribution, *B. sensibilis* was a much rarer species, believing that *B. sensibilis* should either be or resemble the parental form of *B. tabacina* (Mont. & Bosch) Hale. In turn, *B. tabacina* (L! lectotype, duplicate at PC!) differs by the formation of laminal isidia, a uniformly black lower cortex, and by the averagely larger ascospores 9.0–16.0 × 5.0–8.0 µm.

Bulbothrix bulbochaeta (Hale) Hale (LWG! holotype, US! isotype) differs by the narrower laciniae ca. 1.0–2.5 mm wide, the branched cilia and rhizines, the constant presence of laminal ciliary bulbs, the coronate apothecia containing very small and rounded ascospores 4.0–6.0 × 3.0–4.0 µm and by the absence of medullary substances.

Bulbothrix linteolocarpa Marcelli was compared to *B. sensibilis* by Marcelli (1993), and differs by the linear, narrower and truncated laciniae 0.2–0.6 (–0.8) mm wide, the brown lower cortex, the very adnate, distended plane apothecia containing larger ascospores 12.0–16.0 ×6.0–8.0 µm, and by the frequent cilia with smaller bulbs (similar in size and aspect to those found in *Bulbothrix* species containing gyrophoric acid) and longer apices.

Bulbothrix meizospora (Steiner & Zahlbruckner) Hale differs by the laciniae usually more irregularly branched and with rounded apices, and by the always larger ascospores, measuring 12.0–22.0 × 8.0–12.0 µm. Comparatively, thalli of *B. sensibilis* are also more evidently maculate.

***Bulbothrix setschwanensis* (Zahlb.) Hale. Phytologia 28: 481. 1974.**
Mycobank: MB 341613
Figure 16

Basionym: *Parmelia setschwanensis* Zahlb. Symbolae Sinicae 3: 184. 1930.

Holotype. China, Prov. Setschwan austro-occid., in regionis siccae subtropicae convallis fluminis Yalung ad septentriones oppidi Yneyünen infra castelum Kwapi ram *Pistacia weinmannifolia* supra vic. Otang, alt. 2400–2500 m., leg. Handel-Mazzetti 2739, 30-V-1914 (WU!).

Description. Thallus subirregularly to sublinearly laciniate, greenish gray in the herbarium, up to 7.0 cm diam., subcoriaceous, corticolous or ramulicolous; upper cortex 15.0–20.0 µm thick, algal layer 30.0–47.5 µm thick, medulla 87.5–110.0 µm thick, lower cortex 12.5–20.0 µm thick. Laciniae irregularly to partially to anisotomically dichotomously branched, contiguous to imbricate, 1.1–3.5 (-5.0) mm wide, adnate and adpressed, with ±flat, subrounded to subtruncate apices; margins flat, smooth and sinuous to crenate or or irregular, entire to slightly incised, occasionally sublacinulate; axils oval or irregular. Upper cortex mostly smooth and continuous, occasionally becoming subrugose and irregularly cracked; laminal ciliary bulbs absent. Adventitious marginal lacinulae scarce on older parts, short, 0.2–1.0 × 0.1–0.6 mm, plane, simple to irregularly branched; apices truncate or acute; lower side concolor with the lower marginal zone. Maculae absent. Cilia black, without or with simple apices, 0.05–0.30 (–0.50) × ca.

0.03 mm, with semi-immersed to emerse bulbate bases 0.05–0.25 mm wide, frequent to abundant along the margins, spaced 0.05–0.15 mm from each other to rarely contiguous, solitary or in small groups at the crenae and axils becoming scarce at the apices of the laciniae. Soredia, Isidia and Pustulae absent. Medulla white. Lower surface pale brown, opaque, smooth to subrugose, moderately rhizinate. Marginal zone pale brown, indistinctly delimited from the center, opaque, smooth to subrugose, weakly papillate, variably rhizinate. Rhizines brown or cream colored, simple, rarely with subtle displaced blackish bulbs, 0.05–0.80 × 0.03–0.05 mm, frequent becoming abundant near the margins, evenly distributed. Apothecia subconcave to plane, adnate to subpedicelate, 0.4–4.1 mm diam., laminal to submarginal, ecoronate; margin smooth to subcrenate or fissured; amphitecia smooth, without ornamentations. Disc light to dark brown, epruinose, imperforate; epithecium 7.5–12.5 mm high; hymenium 35.0–42.5 µm high; subhymenium 12.5–20.0 µm high. Ascospores ellipsoid to oval, (10.0–) 12.0–19.0 × 6.0–9.0 (–10.0) µm; epispore ca. 1.0 µm. Pycnidia laminal, frequent, immerse, with black ostioles. Conidia baciliform to weakly bifusiform (4.0–) 5.0–8.5 × ca. 0.75 µm.

TLC/HPLC: cortical atranorin and chloroatranorin, medullary salazinic and consalazinic acids (see also Hale 1976).

Distribution. Asia: China (Zahlbruckner 1930, Hale 1976a), India (Hale 1976a, Divakar and Upreti 2005), Nepal (Hale 1976a, Kurokawa 1993, Divakar and Upreti 2005) and Thailand (Wolseley and Aguirre-Hudson 1997, Wolseley et al. 2002, Ramkhamhaeng University Herbarium 2006).

Additional specimens examined. India, Oriental India, prov. Central, Chavradadar, Manra distr., 3500 ft., leg. J.Masten s.n., XII-1900 (NY). Idem, Kolhapur, Maharashtra, Panhala Forest, leg. P. G. Pahvardhan & R. A. V. Prabhu 74.1007, 13-X-1974 (US). Idem, Índia, E. Himalayas, Darjeeling, West Bengal, Manibhanjan, 7700 ft., leg. C. G. Dharne & K. N. R. Chaudhuri 82, VI-1966 (SP). Pakistan, Lower Topa, Murree hills, on bark of Pinus excelsa, leg. S. H. Iqbal 844(?), 11-VII-1967 (US).

Comments. The holotype (Fig. 16) consists of a thallus on a tree twig, together with other bark fragments containing smaller pieces. It is in a reasonable state of preservation, with some lobes and apothecia badly damaged. The material contains several apothecia at different stages of maturity with ascospores in good condition, and many pycnidia with conidia. There are some loose fragments, on which the lower cortex was observed.

Zahlbruckner (1930) described the species as not ciliate ("in marginibus non ciliatis"), since like Lynge (1914) thought that the bulbate cilia on the margins were rhizines. Zahlbruckner (1930) described the lower cortex as black with brown margins (subtus niger, excepta parte angusta marginali castaneo-fusca), but the analysis of the type material confirmed the statements of Hale (1976a) and Divakar and Upreti (2005) on the color to be pale brown (almost cream in some parts) from the center to the margins.

Zahlbruckner (1930) also mentioned ellipsoid to suboval ascospores 12.0–18.0 × 6.0–10.0 mm, but there is a note from Hale with the lectotype citing 12.0–15.0 × 7.0–8.0 mm, and the ascospores found measure (10.0-) 12.0–15.0 × 7.0–9.0 mm. The syntype was not located (W, according to Hale 1976a), and accordingly to his data probably should have ascospores 12.0–18.0 × 6.0–12.0 µm. Measurements made

by Hale (1976a) and Divakar and Upreti (2005) respectively mention ascospores 12.0–19.0 × 6.0–9.0 and 10.0–19.0 × 6.0–9.0 µm encompassing the measurements mentioned above. The other specimens examined here have similar sized ascospores, generally above 12.0 × 7.0 µm. The occurrence of a similar ascospores size variety also occurs in *B. meizospora* (Nylander) Hale.

Among similar species, *Bulbothrix meizospora* is morphologically close to *B. setschwanensis* including the ascospores of similar size, but the has a distinct black lower cortex with brown margins, as cited by Hale (1976a) and Divakar and Upreti (2005).

Hale (1976a) compared *Bulbothrix setschwanensis* to *B. hypocraea* (Vainio) Hale. This species differs by evident maculae in the upper cortex, the narrower laciniae width (ca. 0.5–2.5 mm wide) and by the smaller sizes of the ascospores (8.0–14.0 × 6.0–8.0 mm). *Bulbothrix sensibilis* (Steiner & Zahlbruckner) Hale and *B. meizospora* cortices both differ from *B. setschwanensis* by the black lower cortex with brown margins, presence of cortical maculae, and in the case of *B. sensibilis*, also by the smaller ascospores 8.0–12.0 × 5.0–7.0 µm. *Bulbothrix linteolocarpa* Marcelli differs by the much narrower sublinear laciniae ca. 0.2–0.5 mm wide, and by the cilia with small bulbs and more evident apices that are more widespread along the margins rather than restricted to the crenae and axils of the laciniae.

Bulbothrix continua (Lynge) Hale differs by the narrower laciniae ca. 1.0–2.0 mm wide and by the smaller ascospores 9.0–13.5 × 5.0–7.5 µm. in direct comparison, morphologically its aspect more closely resembles that of *B. hypocraea*, although the maculations are absent, while that of *B. setschwanensis* is more akin to that of *B. meizospora*. In a key in Hale and Kurokawa (1964) *B. continua* was separated from *B. setschwanensis* solely by the laciniae width and by the geographical distribution, the first thought to be endemic to South America and the other to Asia.

Originally described from China, the species is also known from India and Nepal (Hale 1976a, Divakar and Upreti 2005), where it is endemic to the Himalayan mountain region. *Bulbothrix setschwanensis* has been used in *in vitro* experiments for the production of secondary metabolites and reduction of inhibitory activity or reduction of enzymes (Behera and Makhija 2001, 2002, Behera et al. 2000).

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